CRITERION 505

UNINTERRUPTIBLE POWER SUPPLY SYSTEMS

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RECORD OF REVISIONS

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0	09/10/98	Initial Issue.
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1.0 PURPOSE

The purpose of this Criterion is to establish the minimum requirements and best practices for operation and maintenance of Uninterruptible Power Supply Systems at LANL. There are over 100 facility-level Uninterruptible Power Supply (UPS) Systems at the Los Alamos National Laboratory. There are hundreds more UPS systems associated with users' equipment. Systems range in capacity from 400 VA to 1670 kVA. While the majority of the UPS systems are of the static type, the higher capacity systems are of the rotary type.

The maintenance of UPS systems in accordance with this standard will ensure that power is available for critical loads or safety class loads used to protect health and safety of the public, workers, the environment and to reduce the consequences of postulated events involving nuclear, chemical, or other hazards or having adverse impact on the LANL mission.

UPS systems represent a sizable investment in equipment specifically installed to provide reliable regulated power to critical equipment and systems. Therefore it is essential that UPS systems be maintained in a manner that the UPS itself will not fail.

A review of DOE Occurrence Reports from FY 1995 through FY2000 filtered for "electrical equipment" then for "UPS" yielded 87 occurrences that were categorized and ranked in the following order:

• Battery failure	36	41.4%
• Electronic component failure	6	18.4%
• Maintenance personnel error	7	8.0%
• External event (lightning, cooling, etc.)	5	5.7%
• Poorly written procedure	4	4.6%
• Circuit breaker or fuse failure	3	3.4%
• Old, obsolete equipment	3	3.4%
• Undetermined cause	3	3.4%
• Clogged cooling fan or filter	2	2.3%
• Cable connection failure	2	2.3%
• Bypass switch failure	2	2.3%
• Control switch or indicator light failure	2	2.3%
• Inadequate design of UPS equipment	1	1.1%
• Inadequate operator training	1	1.1%

This document addresses the requirements of LIR 230-05-01(Ref 10.1), "Operations and Maintenance Manual."

Implementation of these requirements and recommendations satisfies DOE Order 430.1A (Ref. 10.2), "Life Cycle Asset Management," Attachment 2 "Contractor Requirements Document," Paragraph 2, Sections A through C, which in part require UC to "…maintain physical assets in a condition suitable for their intended purpose" and employ "preventive, predictive, and corrective maintenance to ensure physical asset availability for planned use and/or proper disposition." Compliance with DOE Order 430.1A is required by Appendix G of the UC Contract.

2.0 SCOPE

The scope of this Criterion includes the routine inspection, testing and preventive and predictive maintenance of Level 1 and Level 2 Uninterruptible Power Supply (UPS) Systems (as defined in NFPA 111, "Standard on Stored Electrical Energy Emergency and Standby Power Systems, Ref. 10.14), of all sizes, al all nuclear and non-nuclear LANL facilities. This Criterion does not address corrective maintenance actions required to repair or replace equipment.

Proper testing and maintenance of UPS batteries is fundamental to a reliable UPS system. This criterion does not address in detail the operation and maintenance of battery systems that may be an integral component of a UPS system. They are addressed within Criterion 511 "Stationary System Batteries".

Proper testing and maintenance of the motor/generator components of rotary UPS systems is fundamental to the reliability of those systems. This criterion does not address in detail the operation and maintenance of rotating equipment. They are addressed within Criterion 510 "AC Motors" and Criterion 506 "Generators" or in NFPA 70B.

Proper testing and maintenance of the circuit breakers in UPS systems is essential to the safety and reliability of the systems. This criterion does not address in detail the operation and maintenance of circuit breakers. They are addressed within Criterion 504 "Low Voltage Electrical Equipment".

This maintenance standard applies to all Level 1 and Level 2 UPS systems.

- Systems covered in this standard include static UPS, rotary UPS, and static bypass switches. Limits of system coverage are from the UPS and bypass AC input circuit breaker(s) through the output circuit breaker of the UPS.
- This standard does not cover the design, selection, installation, or acceptance testing of UPS systems. This standard does not cover input or output distribution systems, wiring or switchgear. Refer to DOE-STD-3003 (Ref 10.7), NFPA-70 (Ref 10.11), NFPA-111 (Ref 10.14), ANSI/IEEE 944 (Ref 10.6), and the LANL Engineering Manual for requirements and guidance in these areas.

- This standard does not cover the assignment of a Management Level to any specific UPS system; refer to LANL LIR 230-01-02 (Ref. 10.8) for guidance in this area.
- This standard does not cover the maintenance of small "commodity" UPS systems dedicated to individual personal computer stations unless the application puts the system in Level 1 or Level 2 as defined in NFPA 111.

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

AHJ	Authority Having Jurisdiction
CFR	Code of Federal Regulations
DOE	Department of Energy
LIG	Laboratory Implementing Guidance
LIR	Laboratory Implementing Requirement
LPR	Laboratory Performance Requirement
O&M	Operations and Maintenance
POC	Point of Contact
PPE	Personal Protective Equipment
PP&PE	Personal Property and Programmatic Equipment
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems, and Components
UC	University of California
UPS	Uninterruptible Power Supply

3.2 Definitions

AC Input. Electric power in the form of alternating current (AC) supplied to the uninterruptible power supply (UPS) and bypass. (IEEE Std 944 (Ref. 10.6), part 2)

AC Input Failure Test. A test performed by interrupting the ac input power or simulated by switching off all UPS rectifiers and bypass feeders at the same time. This test is performed with the dc source available. Output voltage and frequency variations are checked to be within specified limits. (IEEE Std 944 (Ref. 10.6), section 7.4.3)

AC Input Return Test. A test performed by restoring the ac input power or simulated by switching on all UPS rectifiers and bypass feeders at the same time.

UPS rectifier is observed for proper operation. Output voltage and frequency variations are checked to be within specified limits. (IEEE Std 944 (Ref. 10.6), section 7.4.3)

Acceptance Test. A capacity test made on a new UPS installation to determine that it meets applicable codes, specifications, and manufacturer's ratings. (NFPA 111 (Ref 10.14), section 5.6)

Ambient Temperature. The temperature of the medium, such as air, into which the heat of equipment is dissipated.

Battery. A device that transforms stored chemical energy into electric energy. UPS batteries are typically rated at 15 minutes with an end cell voltage of 1.67 volts per cell, whereas a telecommunications battery (for example) is rated at 8 hours with an end cell voltage of 1.75 volts per cell. While a UPS battery is a short duration battery with a high rate of discharge, a telecommunications battery is a long duration battery with a lower rate of discharge. (IEEE Std 944 (Ref. 10.6), part 2)

Battery Charger. A device that can maintain a unidirectional current in a battery in the opposite direction to that during discharge thereby converting electric energy into chemical energy within the battery.

Class. The minimum time, in hours, for which the UPS is designed to operate at its rated load without being recharged. (NFPA 111 (Ref. 10.14), paragraph 2.2.3.)

Class 0.033	0.033 hours (2 minutes)
Class 0.083	0.083 hours (5 minutes)
Class 0.25	0.25 hours (15 minutes)
Class 1.5	1.5 Hours (90 minutes)
Class x	Other time, in hours, as required by the application, code, or user

Harmonic. The sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. (IEEE Std 944 (Ref. 10.6), part 2)

Harmonic-Components Test. A test in which the harmonic components of the output voltage are recorded under rated linear (sine wave) and nonlinear load conditions. (IEEE Std 944 (Ref. 10.6), section 7.4.11)

Inverter. A system that changes direct-current power to alternating-current power. (IEEE Std 944 (Ref. 10.6), part 2)

Level. Performance, installation, and maintenance requirements based on consequence of failure of the UPS. (NFPA 111, paragraph 2.2.5.) (Ref. 10.14)

Level 1 - The most stringent equipment performance requirements for applications where failure of the UPS system to perform could result in loss of human life or serious injury. Level 1 UPS systems are intended to automatically supply illumination or power, or both, to critical areas and equipment in case of failure of the primary supply. Level 1 systems provide power for illumination and

ventilation when essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications system, industrial processes where current interruption would produce serious life safety or health hazards. Level 1 includes UPS systems designated by LANL as ML1 and ML2. Level 1 also includes ML3 UPS systems that supply life safety systems. (NFPA 111, Sections 2.2.5.1 and A-2-2.5.1, LIR 230-04-01 and LIG 230-01-02).

Level 2 - Level 2 UPS systems are applications where the failure of the UPS to perform is less critical to human life and safety. Level 2 UPS systems supply power automatically to selected loads (other than those classed as emergency systems) in case of failure of the primary source. Level 2 systems typically are installed to serve loads such as heating and refrigeration systems, communications systems, ventilation and smoke removal systems, sewerage disposal, lighting, and industrial processes that, when stopped due to any interruption of the primary electrical supply, could create hazards or hamper rescue or fire-fighting operations. Level 2 includes non-life-safety UPS systems designated by LANL as ML3. (NFPA 111, Sections 2.2.5.2 and A-2-2.5.2, LIR 230-04-01 and LIG 230-01-02)

Level 3 - All applications, including optional standby systems, not defined in Levels 1 and 2. (NFPA 111, paragraph 2.2.5.4.) (It is not anticipated that any UPS covered by this criterion will be Level 3)

Light Load Test. A test of the UPS that is performed with normal loads connected to verify that the UPS is properly connected and that all functions operate properly. The following tests are included: (IEEE Std 944 (Ref. 10.6), section 7.4.1)
(1) Measure and record UPS output voltage and frequency.
(2) Check the operation of all control switches, measuring devices, meters, and other means required to determine proper UPS operation.

Load Breaker. Circuit breaker that feeds and protects a load, located between the power source bus and the load. (DOE-STD-3003 (Ref. 10.7), section 3.12)

Management Level. Under LIR 230-01-02 (Ref 10.8), Graded Approach for Facility Work, each UPS system will be assigned a graded approach management level.

Nonlinear Load. A load with such characteristics that with an applied sinusoidal voltage the load current is not sinusoidal. (IEEE Std 944 (Ref. 10.6), part 2)

Off-line UPS. UPS that normally serves UPS loads from utility source alternating current. An off-line UPS maintains battery charge and, when the utility source fails, converts battery source power to alternating current to serve the UPS load.

On-line UPS. UPS that continuously derives alternating current output power from direct current. An on-line UPS rectifies utility source alternating current to direct current. Some of the DC power is used to maintain battery charge. The remaining DC power from the rectifier is converted to alternating current to serve the UPS load.

When the utility source fails, the on-line UPS converts battery source power to alternating current to serve the UPS load.

Output Breaker. Circuit breaker located between the UPS output terminals and the bus feeding the loads, intended to protect the UPS from various fault conditions and to provide a means to connect and disconnect the UPS from its load. (DOE-STD-3003 (Ref. 10.7), section 3.13)

Output Voltage. The root-mean-square (RMS) voltage between the output terminals.

Output Voltage Balance Test. A test of three-phase UPS systems in which the phase-to-phase and phase to neutral output voltages are recorded during the following conditions:
(1) Symmetrical load conditions
(2) Unbalanced load conditions from no load to full load.
Phase angle deviations are either measured or derived by calculation from the values of phase-to-phase and phase-to-neutral voltages. (IEEE Std 944 (Ref. 10.6), section 7.4.8)

Rectifier. A device that changes alternating-current power to direct-current power to supply the input power to an inverter but not to a battery. (IEEE Std 944 (Ref. 10.6), part 2)

Rectifier/Charger. A device that changes alternating-current power to direct-current power to feed either an inverter or a battery, or both. (IEEE Std 944 (Ref. 10.6), part 2)

Safety Class. Safety-class SSCs are systems, structures, or components whose preventive or mitigative function is necessary to keep hazardous material exposure to the public below the offsite Evaluation Guidelines. This definition would typically exclude items such as primary environmental monitors and most process equipment. (DOE-STD-3009 (Ref.10.15))

Safety Significant. Structures, systems, and components not designated as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis. (DOE-STD-3009 (Ref. 10.15))

Static Bypass Switch. A high-speed solid-state switch, usually internal to the UPS, that will automatically operate during an overload or in case of a fault in the UPS. The UPS is effectively removed from the circuit and the load is connected directly to the ac input.

Synchronization. Bringing one AC power source of the same nominal frequency as another into the same frequency and phase angle of the other in order to avoid excessive current flow when paralleling the two AC power sources. (DOE –STD-3003-2000 (Ref. 10.7), section 3.18)

Synchronization Test. A test performed on UPS systems for which synchronization with an alternate source is required. Variation frequency limits are tested using a variable frequency generator. The rate of change of frequency during synchronization and the UPS output voltage are measured. (IEEE Std 944 (Ref. 10.6), section 7.4.2)

Transfer Test – Forward and Reverse. A test performed on UPS systems that have a static bypass switch. Transients, such as maximum and minimum voltages, and transfer times are measured during load transfer to and from the bypass source. (IEEE Std 944 (Ref. 10.6), section 7.4.5)

Type. The maximum time, in seconds, that the UPS will permit the terminals of the transfer switch to be without acceptable electrical power. (NFPA 111 (Ref. 10.14), paragraph 2.2.2.)

Type 0 No interruptions—UPS carrying load, 0 seconds.
Type U Basically uninterruptible UPS system with utility as preferred source.

Uninterruptible Power Supply (UPS). A system that converts unregulated input power to voltage and frequency controlled, sinusoidal wave AC power that continues without interruption, for a finite period of time, even with the deterioration of the AC input power. (IEEE Std 944 (Ref. 10.6), part 2) A UPS system may consist of one or more UPS modules connected to obtain the required capacity, to provide added reliability through redundancy, or both.

1. The function of a UPS is to supply a continuous source of quality power for a given length of time, of required capacity, to systems sensitive to disturbances after loss, failure or degradation of the normal power supply.
    a. Continuous output is independent of short interruptions or irregularities in the input power source.
    b. Quality power implies a nearly sinusoidal voltage output, of reasonably constant RMS value, having an acceptably low total harmonic distortion and no adverse transients.
2. There are two principal types of UPS: static and rotary.
    a. **Static UPS**: As the name implies, a static UPS has no moving energy conversion parts, but instead uses solid-state devices for energy conversion. Static UPS may be either "ON-LINE" or "OFF-LINE". A static UPS consists of a rectifier/charger, a battery, an inverter and usually a static bypass switch; refer to Appendix D. The rectifier/charger converts incoming AC power to DC power to feed the battery and the inverter. Energy is electro-chemically stored in the battery and can supply the UPS load for a finite time, usually on the order of 15 minutes. The inverter converts DC power from either the rectifier/charger or the battery to almost pure sine wave AC power with nearly constant voltage and frequency to serve the UPS load. The static bypass switch provides a near-instantaneous connection of loads to the AC power source should the

UPS fail. Solid state power devices are highly reliable, but since the UPS contains many individual devices and usually operates continuously, electronic component failures will occur, particularly in the inverter. However the most common static UPS failure point is the battery.

b. **Rotary UPS**: As the name implies, a rotary UPS uses a motor/generator for isolation and energy conversion. A typical hybrid rotary UPS consists of a rectifier/charger, a battery, an inverter, a synchronous motor/generator, and usually bypass switches; refer to Appendix E. The rectifier/charger converts incoming AC power to DC power to feed the battery and the inverter. Energy is electro-chemically stored in the battery and can supply the UPS load for a finite time, usually on the order of 15 minutes. The inverter converts DC power from either the rectifier/charger or the battery to square wave AC power with constant frequency to drive the motor-generator. The synchronous motor/generator derives almost pure sine wave AC power with nearly constant voltage and frequency to serve the UPS load. A bypass switch is usually available to connect the motor/generator directly to the AC input power in the event of a rectifier or inverter failure. A second bypass switch is often available to connect the UPS load to the AC input power in the event of a motor/generator failure. The most common rotary UPS failure point is the battery.

   Rotary UPS systems also include inertia based systems which us a spinning flywheel or highly compressed gas to "ride through" momentary transients.

Redundant UPS Systems. UPS systems may consist of several UPS modules connected to provide redundancy in the event of an individual UPS module malfunction or failure. Refer to Appendix F.

UPS Module. A single, self-contained enclosure containing the power and control elements needed to achieve uninterrupted operation. These components include transformers, rectifier, inverter, and protective devices.

4.0 RESPONSIBILITIES

4.1 FWO-Systems, Engineering and Maintenance (SEM)

4.1.1 FWO-SEM is responsible for the technical content of this Criterion and monitoring the applicability and the implementation status of this Criteria and either assisting the organizations that are not applying or meeting the implementation expectations contained herein or elevating their concerns to the director(s).

Basis: LIR 301-00-01.11; Issuing and Managing Laboratory Operations Implementation Requirements and Guidance, Section 5.4, OIC Implementation Requirements.

4.1.2 FWO-SEM shall provide technical assistance to support implementation of this Criterion.

4.2 Facility Manager

4.2.1 Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE) under their jurisdiction, in accordance with the requirements of this document.

4.2.2 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

4.3 Group Leader

4.3.1 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that are under their jurisdiction

4.3.2 Responsible for system performance analysis and subsequent replacement or refurbishment of assigned PP&PE.

4.4 Authority Having Jurisdiction (AHJ) - POC for Electrical Chapter of LANL Engineering Manual

The AHJ is responsible for providing a decision on a specific technical question regarding this criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. A compilation of all applicable precautions shall be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards/precautions that may not be immediately obvious.

5.1.1 It is important to avoid unintentional interruption of the power output of the UPS system. Extreme caution should be used when servicing the system to prevent unscheduled outages. UPS maintenance should be scheduled at times that will least affect operations. Actual maintenance procedures should not be started until the users have been notified. (Research of 87 DOE ORPS reports describing UPS occurrences from FY1995 through FY2000 revealed that UPS operating and switching errors by maintenance personnel were the third leading cause of UPS occurrences.) (NFPA 70B (Ref. 10.12), section 22-2.1)

5.1.2 Only fully trained and qualified persons with proper test equipment and personal protective equipment should be authorized to perform UPS maintenance. (LIR 402-600-01 (Ref. 10.16) section 7.3.3; NFPA 70E (Ref. 10.13) Part II section 3-1 and Part III section 2-1.)

5.1.3 A specific lock-out/tag-out procedure should be developed for the maintenance of each UPS system. UPS systems present a special lock-out/tag-out challenge for the reasons outlined below: (LIR 402-860-01 (Ref. 10.17), Section 5.5)

5.1.3.1 Even with the UPS cabinet power switches OFF, hazardous electrical energy may remain inside the cabinet of a UPS. There are often multiple sources of electrical energy to a UPS cabinet—external disconnects or circuit breakers should be used to completely isolate the UPS cabinet from AC and DC power sources. Capacitors within the UPS can retain hazardous electrical charge—they should be discharged and checked by a qualified person. The UPS batteries may be within the cabinet, and dangerous DC energy can exist when all external power has been disconnected.

5.1.3.2 A rotary UPS contains electrical hazards like a static UPS plus mechanical hazards such as rotating shafts, belts, and pulleys. After switching off a rotary UPS, the machine should be allowed to come to a complete standstill—a rotary UPS can generate hazardous voltage even when spinning at low RPM.

5.1.4 UPS systems are very equipment-specific. The manufacturer's instructions should be followed carefully when performing maintenance on UPS equipment. (NFPA 70B (Ref. 10.12), Section 22-1)

5.1.5 The integrity of the grounding system must be maintained as required by Article 250 of the National Electrical Code. For separately derived systems (most UPS systems are), ascertain that the neutral is properly grounded. (NFPA 70B (Ref. 10.12), Section 22-2.1.8)

5.1.6 UPS systems are generally protected with special fuses. Installing an improper fuse in a UPS can result in severe damage to the UPS and the load equipment. It is especially important that an ample supply of the proper types and sizes of spare fuses be maintained. Replace fuses only with fuses having the same or lower current ratings and the same types. (NFPA 70B (Ref. 10.12), section 22-2.2.3)

5.1.7 Environment of the UPS must be kept clean. Take particular care to prevent metallic or other electrically conducting dust particles from being sucked into air inlets.

5.2 Limitations

The intent of this Criterion is to identify the minimum generic requirements and recommendations for SSC operation and maintenance across the Laboratory. Each user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, vendor O&M requirements and guidance, etc.).

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities shall implement the requirements of DOE Order 4330.4B (Ref. 10.3) as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or CFR identified above.

6.0 REQUIREMENTS

Minimum requirements that Criterion users shall follow are specified in this section. Requested variances to these requirements shall be prepared and submitted to FWO-SEM in accordance with LIR 301-00-02 (Ref. 10.4), "Variances and Exceptions to Laboratory Operations Requirements," for review and approval. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgement, safety matters, and operations and maintenance experience drive the requirements contained in this section.

6.1 Operations Requirements

6.1.1 Post Repair Testing

Immediately following any UPS system repair or battery replacement, perform all inspections specified under 6.2.3.1 then test the UPS under connected load for a minimum of 5 minutes or as specified for the UPS class, whichever is less. Take corrective action for any item found to be deficient.

Basis: NFPA 111 (Ref. 10.14), Section 6.3.3 (4). Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2 Maintenance Requirements

6.2.1 General

6.2.1.1 Provide preventive, predictive and corrective maintenance to ensure UPS availability for the planned use. Maintain the UPS to ensure to a reasonable degree that the system is capable of supplying the service quality within the time specified for the type and for the time duration specified for the class.

Basis: DOE O 430.1A (Ref. 10.2), Attachment 2, Paragraph 2.c.; NFPA 111 (Ref. 10.14), Section 6.3.1

6.2.1.2 Initiate a program for routine UPS maintenance and operational testing immediately following initial acceptance, or any repair or component replacement, including batteries.

Basis: NFPA 111 (Ref. 10.14), Section 6.3.2. Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.2 Personnel Qualifications

Properly qualified and trained personnel shall perform maintenance on UPS systems.

Basis: LIR 402-600-01 (Ref. 10.16); NFPA 111 (Ref. 10.14), Section 6.4.5 Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.3 Monthly Intervals

6.2.3.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

Inspect each Level 1 UPS system monthly. Take corrective action for any item found to be deficient. Each inspection shall include the following:

A. Check the battery and associated charger/control equipment to verify that they are in a clean and satisfactory condition and no exceptional environmental or other conditions exist that could damage or affect performance. (Refer to Criterion 511 “Stationary System Batteries” for additional requirements and recommendations.)

B. When applicable, check the battery electrolyte levels and refill as necessary. Clean and regrease battery terminals and intercell connectors as necessary. Clean cell tops. (Refer to Criterion 511 “Stationary System Batteries” for additional requirements and recommendations.)

C. Check and record individual cell voltages where practical. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)
D. Check and record the specific gravity of pilot cells where applicable. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)
E. Note the condition of the plates and sediment of free-electrolyte, lead-acid batteries in transparent containers. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)
F. Perform a load test. Record the UPS output voltage, the battery voltage, and the duration of the test at the beginning and end of the test.
G. Check that all indicator lamps, meters, and controls are operating correctly.
H. Check the load value to ensure that it is within the UPS rating.

Basis: *NFPA* 111 (Ref. 10.14), Section 6.4.1 and 6.4.2. Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.3.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

No requirements other than those in 6.2.1.

6.2.3.3 ML4 Systems

No requirements.

6.2.4 Quarterly Intervals

6.2.4.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

Exercise each Level 1 UPS system under connected load for a minimum of 5 minutes or as specified for the UPS class, whichever is less. Take corrective action for any item found to be deficient.

Basis: *NFPA* 111 (Ref. 10.14), Sections 6.4.1. Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.4.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

No requirements other than those in 6.2.1.

6.2.4.3 ML4 Systems

No requirements.

6.2.5 Annual Intervals

6.2.5.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

Test each Level 1 UPS system under full rated load the full duration of its class. Take corrective action for any item found to be deficient.

Basis: NFPA 111 (Ref. 10.14), Sections 6.4.3. Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.5.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

No requirements other than those in 6.2.1.

6.2.5.3 ML4 Systems

No requirements.

7.0 RECOMMENDATIONS AND GOOD PRACTICES

The information provided in this section is recommended based on acceptable industry practices and should be implemented by each user based on his/her unique application and operating history of the subject systems/equipment.

7.1 Operations Recommendations

7.1.1 General

7.1.1.1 Whenever additional loads are connected to the UPS, check the protective device coordination, calibration, and proper operation of the modified system; perform *Light Load Test* and *Harmonic Components Test*.

Basis: NFPA 70B (Ref. 10.12), section 22-2.2.8

7.1.1.2 Intervals for recommended operational inspection should take into consideration the type of service to which the UPS is subjected (duty cycle, chemicals, dust, heat), manufacturer's recommendations, and trending.

Basis: DOE-STD-3003 (Ref. 10.7), Section 5.3.2.

7.1.2 Personnel Qualifications.

Specific qualification for UPS operation personnel should include the following:

(1) Fundamentals of electrical and electronic design of UPSs

(2) Testing and maintenance practices for UPS systems
(3) Safety precautions for UPS systems
(4) LANL Electrical Safety Training per LIR 402-600-01

Basis: DOE-STD-3003 (Ref. 10.7), section 5.3.2.1

7.1.3 Daily Intervals

UPS should be checked externally daily. The UPS should be checked for evidence of problems by evaluating meter readings, sounds, smells, and detrimental environmental problems (heat, moisture, and chemicals).

Basis: DOE-STD-3003 (Ref. 10.7), section 5.3.2.2

7.1.4 Weekly Intervals

7.1.4.1 All lamps should be checked using the "lamp test" feature.

Basis: IEEE 446 (Ref 10.18), section 8.5

7.1.4.2 All meters should be checked to ensure they are operating.

Basis: IEEE 446 (Ref 10.18), section 8.5

7.1.4.3 Meter readings should be recorded: voltmeter, ammeter, and frequency meter at input and output.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.7(b)

7.1.4.4 Operational status of the disturbance monitor should be verified, if the UPS system is so equipped.

Basis: IEEE 446 (Ref 10.18), Section 8.5

7.1.4.5 The appearance and cleanliness of all UPS equipment and the UPS room/area should be checked.

Basis: IEEE 446 (Ref 10.18), Section 8.5

7.1.4.6 The UPS room/area HVAC equipment should be checked and the room/area temperature and humidity should be measured.

Basis: IEEE 446 (Ref 10.18), Section 8.5

7.1.4.7 All UPS equipment air intakes and exhausts, including filters, should be checked.

Basis: IEEE 446 (Ref 10.18), Section 8.5

7.1.5 Bi-Annual Intervals

UPS manufacturer should be contacted for information on equipment upgrades and recommended revisions.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.11

7.2 Maintenance Recommendations

7.2.1 Personnel Qualifications.

Specific qualification for UPS maintenance personnel should include the following:
(1) Fundamentals of electrical and electronic design of UPSs
(2) Testing and maintenance practices for UPS systems
(3) Safety precautions for UPS systems

Basis: DOE-STD-3003 (Ref. 10.7), section 5.3.2.1

7.2.2 Maintenance Intervals

7.2.2.1 Intervals for recommended operational inspection and testing should take into consideration the type of service to which the UPS is subjected (duty cycle, chemicals, dust, heat), age and condition of the equipment, manufacturer's recommendations, and trending.

Basis: DOE-STD-3003 (Ref. 10.7), Section 5.3.2; NETA MTS-2001 (Ref. 10.10), Appendix B.

7.2.3 Monthly Intervals

7.2.3.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

A. Static Systems: UPS phase and neutral output currents should be measured during peak loading. Measurement should be made using a true RMS type ammeter to verify that the neutral conductor ampacity is not exceeded.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.8 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to NFPA 70B recommendations for Level 2 systems.

B. Static Systems: All parts should be inspected for evidence of overheating.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 & 9 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-

2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

C. Static Systems: All parts should be inspected for evidence of physical damage, including worn insulation and corrosion.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

D. Static Systems: Terminals should be inspected for loose or broken connections, burned insulation, etc.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

E. Static Systems: UPS should be checked for liquid contamination (battery electrolyte, oil from capacitors, etc.) Inverter should be checked for signs of leaking fluid from the wave-forming capacitors; capacitors should be checked for swelling or discoloration.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.9 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

F. Static Systems: The inside of all UPS equipment enclosures the components within should be cleaned

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

7.2.3.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

No recommendations.

7.2.3.3 ML4 Systems

No recommendations.

7.2.4 Quarterly Intervals

7.2.4.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

A. Rotary Systems: All parts should be inspected for evidence of overheating.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 & 9 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

B. Rotary Systems: All parts should be inspected for evidence of physical damage, including worn insulation and corrosion.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

C. Rotary Systems: Terminals should be inspected for loose or broken connections, burned insulation, etc.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

D. Rotary Systems: Check connections for tightness.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 and NFPA 70B recommendations for Level 2 systems.

E. Rotary Systems: The inside of all UPS equipment enclosures the components within should be cleaned

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

F. Rotary Systems: All bearings and their lubrication should be checked. Refer to Criterion 510, AC Motors, for additional guidance on maintenance of rotating equipment.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

G. Rotary Systems: The alarm shutdown functions should be checked.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std.446 recommendations for Level 2 systems.

7.2.4.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

A. The UPS battery and associated charger/control equipment should be checked to verify that they are in a clean and satisfactory condition and no exceptional environmental or other conditions exist that could damage or affect performance. (Refer to Criterion 511 “Stationary System Batteries” for additional recommendations.)

B. When applicable, the UPS battery electrolyte levels should be checked and refilled as necessary. Battery terminals and intercell connectors should be cleaned and re-greased as necessary. Cell tops should be cleaned. (Refer to Criterion 511 “Stationary System Batteries” for additional recommendations.)

C. Individual cell voltages should be checked and recorded where practical. (Refer to Criterion 511 “Stationary System Batteries” for additional recommendations.)

D. The specific gravity of pilot cells should be checked and recorded where applicable. (Refer to Criterion 511 “Stationary System Batteries” for additional recommendations.)

E. The condition of the plates and sediment of free-electrolyte, lead-acid batteries in transparent containers should be noted. (Refer to Criterion 511 “Stationary System Batteries” for additional recommendations.)

F. A load test should be performed. The UPS output voltage, the battery voltage, and the duration of the test at the beginning and end of the test should be recorded.

G. Correct operation of all UPS indicator lamps, meters, and controls should be checked.

H. The UPS load value should be checked to ensure that it is within the UPS rating.

Basis: *NFPA* 111 (Ref. 10.14), Section 6.4.1 and 6.4.2 for Level 1 Systems. Recommendation for Level 2 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to NFPA 111 requirement for Level 1 systems.

I. Static Systems: UPS phase and neutral output currents should be measured during peak loading. Measurement should be made using a true RMS type ammeter to verify that the neutral conductor ampacity is not exceeded.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.8 (Assumed to be for Level 2 Systems.)

J. Static Systems: All parts should be inspected for evidence of overheating.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 & 9 (Assumed to be for Level 2 Systems.)

K. Static Systems: All parts should be inspected for evidence of physical damage, including worn insulation and corrosion.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 (Assumed to be for Level 2 Systems.)

L. Static Systems: Terminals should be inspected for loose or broken connections, burned insulation, etc.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 (Assumed to be for Level 2 Systems.)

M. Static Systems: UPS should be checked for liquid contamination (battery electrolyte, oil from capacitors, etc.) Inverter should be checked for signs of leaking fluid from the wave-forming capacitors; capacitors should be checked for swelling or discoloration.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 and NFPA 70B (Ref. 10.12), Section 22-2.1.9 (Assumed to be for Level 2 Systems.)

N. Static Systems: The inside of all UPS equipment enclosures the components within should be cleaned

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 (Assumed to be for Level 2 Systems.)

7.2.4.3 ML4 Systems

No recommendations.

7.2.5 Semi-Annual Intervals

7.2.5.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

A. The tightness of electrical connections should be checked and utilizing infrared scanning or testing with a digital low-resistance ohmmeter to identify possible loose or corroded connections. Clean and re-tighten as necessary.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.8 and 22-2.1.9 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to NFPA 70B recommendations for Level 2 systems.

B. Static Systems: UPS output voltage and frequency should be checked and adjusted according to the manufacturer's specifications.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std. 446 recommendations for Level 2 systems.

C. Static Systems: Alarm shutdown functions should be checked.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std. 446 recommendations for Level 2 systems.

7.2.5.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

A. The UPS system should be exercised under connected load for a minimum of 5 minutes or as specified for the UPS class, whichever is less.

Basis: *NFPA* 111 (Ref. 10.14), Section 6.4.1 and 6.4.2 for Level 1 Systems. Recommendation for Level 2 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to NFPA 111 requirement for Level 1 systems.

B. Rotary Systems: All parts should be inspected for evidence of overheating.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 & 9 (Assumed to be for Level 2 Systems.)

C. Rotary Systems: All parts should be inspected for evidence of physical damage, including worn insulation and corrosion.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8 (Assumed to be for Level 2 Systems.)

D. Rotary Systems: Terminals should be inspected for loose or broken connections, burned insulation, etc.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3(Assumed to be for Level 2 Systems.)

E. Rotary Systems: Check connections for tightness.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 and NFPA 70B (Ref. 10.12), Section 22-2.1.8. (Assumed to be for Level 2 Systems.)

F. Rotary Systems: The inside of all UPS equipment enclosures the components within should be cleaned

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 (Assumed to be for Level 2 Systems.)

G. Rotary Systems: All bearings and their lubrication should be checked. Refer to Criterion 510, AC Motors, for additional guidance on maintenance of rotating equipment.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 (Assumed to be for Level 2 Systems.)

H. Rotary Systems: The alarm shutdown functions should be checked.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.3 (Assumed to be for Level 2 Systems.)

7.2.5.3 ML4 Systems

No recommendations.

7.2.6 Annual Intervals

7.2.6.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

A. Light-load test should be performed. Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions. Proper operation of control switches and meters should be verified.

B. Synchronization test should be performed if synchronization with an alternate source is required. The rate of change of inverter frequency should be measured while a reference frequency is attenuated. The inverter output voltage should be measured concurrently. Results should be within limits specified by the UPS manufacturer's instructions.

C. AC input failure test should be performed. The input power source(s) should be disconnected or the rectifier should be shut down on-line to verify that the DC source can indeed instantly sustain the critical loads. Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions.

D. AC input return test should be performed. The input power source(s) should be restored or the rectifier reactivated on-line to verify that the rectifier can instantly sustain the critical loads and recharge batteries (if used). Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions.

E. Transfer test should be performed for UPS systems that use a Static Bypass Switch. The UPS should be cycled to and from the bypass source. Transients, maximum and minimum voltages, and transfer times should be verified to remain within limits specified by the UPS manufacturer's instructions. Simulated failures may be needed.

F. Static Systems: Output-voltage balance test should be performed. Inverter phase-to-phase and phase-to-neutral voltage and angles should be measured while symmetrical loads are applied. Inverter phase-to-phase and phase-to-neutral voltages and angles should be measured during the transition from no-load to an unbalanced full-load. Voltages and phase angles should be verified to remain within limits specified by the UPS manufacturer's instructions.

G. Static Systems: Harmonic-components test should be performed. Harmonic content in the output voltage should be measured for rated linear and non-linear load conditions and verified to remain within limits specified by the UPS manufacturer's instructions.

Basis: DOE-STD-3003 (Ref. 10.7), Section 5.3.3 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to DOE-STD-3003 recommendations for Level 2 systems.

7.2.6.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

H. The tightness of electrical connections should be checked and utilizing infrared scanning or testing with a digital low-resistance ohmmeter to identify possible loose or corroded connections. Clean and re-tighten as necessary.

Basis: NFPA 70B (Ref. 10.12), Section 22-2.1.8 and 22-2.1.9 for (assumed) Level 2 Systems.

I. Static Systems: UPS output voltage and frequency should be checked and adjusted according to the manufacturer's specifications.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems.

J. Static Systems: Alarm shutdown functions should be checked.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5.2 for (assumed) Level 2 Systems.

7.2.6.3 ML4 Systems

No recommendations.

7.2.7 18 Month Intervals

7.2.7.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

A. All UPS circuit breakers should be checked and tested. Refer to Criterion 504, Low Voltage Electrical Equipment, for additional guidance on maintenance of circuit breakers.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5 for (assumed) Level 2 Systems. Recommendations for Level 1 systems derived by applying Appendix B of NETA MTS-2001 (Ref. 10.10) to IEEE Std. 446 recommendations for Level 2 systems.

7.2.7.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

A. Light-load test should be performed. Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions. Proper operation of control switches and meters should be verified.

B. Synchronization test should be performed if synchronization with an alternate source is required. The rate of change of inverter frequency should be measured while a reference frequency is attenuated. The inverter output voltage should be measured concurrently. Results should be within limits specified by the UPS manufacturer's instructions.

C. AC input failure test should be performed. The input power source(s) should be disconnected or the rectifier should be shut down on-line to verify that the DC source can indeed instantly sustain the critical loads. Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions.

D. AC input return test should be performed. The input power source(s) should be restored or the rectifier reactivated on-line to verify that the rectifier can instantly sustain the critical loads and recharge batteries (if used). Inverter voltage and frequency should be verified to remain within limits specified by the UPS manufacturer's instructions.

E. Transfer test should be performed for UPS systems that use a Static Bypass Switch. The UPS should be cycled to and from the bypass source. Transients, maximum and minimum voltages, and transfer times should be verified to remain within limits specified by the UPS manufacturer's instructions. Simulated failures may be needed.

F. Static Systems: Output-voltage balance test should be performed. Inverter phase-to-phase and phase-to-neutral voltage and angles should be measured while symmetrical loads are applied. Inverter phase-to-phase and phase-to-neutral voltages and angles should be measured during the transition from no-load to an unbalanced full-load. Voltages and phase angles should be verified to remain within limits specified by the UPS manufacturer's instructions.

G. Static Systems: Harmonic-components test should be performed. Harmonic content in the output voltage should be measured for rated linear and non-linear load conditions and verified to remain within limits specified by the UPS manufacturer's instructions.

Basis: DOE-STD-3003 (Ref. 10.7), Section 5.3.3 for (assumed) Level 2 Systems.

7.2.7.3 ML4 Systems

No recommendations.

7.2.8 Bi-Annual Intervals

7.2.8.1 ML1, ML2, and those ML3 systems affecting life safety (NFPA 111 Level 1 Systems)

No recommendations.

7.2.8.2 ML3 systems NOT affecting life safety (NFPA 111 Level 2 Systems)

All UPS circuit breakers should be checked and tested. Refer to Criterion 504, Low Voltage Electrical Equipment, for additional guidance on maintenance of circuit breakers.

Basis: IEEE Std. 446 (Ref 10.18), Section 8.5 for (assumed) Level 2 systems.

7.2.8.3 ML4 Systems

No recommendations.

8.0 GUIDANCE

8.1 Operations Guidance

8.1.1 Appendix A is a chart showing intervals for the UPS systems operations described in parts 6.1 and 7.1 of this document.

8.2 Maintenance Guidance

8.2.1 Appendix B is a chart showing intervals for the UPS systems maintenance described in parts 6.2 and 7.2 of this document.

8.2.2 Appendix C is information about the expected life of UPS system components and guidance for their scheduled replacement.

9.0 REQUIRED DOCUMENTATION

9.1 Maintenance History

Maintenance history shall be maintained for UPS systems to include, as a minimum, the parameters listed in the Table 9-1 below:

Table 9-1 Documentation Parameters

MAINTENANCE HISTORY DOCUMENTATION PARAMETERS				
PARAMETER	**ML1**	**ML2**	**ML3 affecting life safety**	**ML3 NOT affecting life safety**
Maintenance Activities				
Maintenance Date	**X**	**X**	**X**	**X**
PM Activities Performed	**X**	**X**	**X**	**X**
Parts Replaced	**X**	**X**	**X**	**X**
Modifications Made	**X**	**X**	**X**	**X**
Post Maintenance Testing Performed	**X**	**X**	**X**	**X**
Identification of Maintenance Personnel	**X**	**X**	**X**	**X**
Equipment Problems				
Failure Dates	**X**	**X**	**X**	**X**
Failure Root Cause	**X**	**X**	**X**	**X**

Corrective Actions Taken	X	X	X	X
Parts Replaced	X	X	X	X
Post-Repair Testing Performed	X	X	X	X
Date Returned to Service	X	X	X	X
Identification of Servicing Personnel	X	X	X	X
Inspection Results				
Inspection Date	X	X	X	X
Inspection Performed	X	X	X	X
Tests Performed	X	X	X	X
UPS Condition	X	X	X	X
Meter Readings	X	X	X	X
Identification of Inspecting Personnel	X	X	X	X

Basis: Documentation of the parameters listed in Table 9-1 above satisfies the requirements of LPR 230-07-00, Criteria 2, (Ref. 10.5) which states; "Maintenance activities, equipment problems, and inspection and test results are documented." NFPA 111 (Ref. 10.14), section 6.3.3, requires that a written record of all inspections, tests, and repairs be maintained on the premises.

9.2 Instruction Manuals

One set of instruction manuals shall be kept with each UPS system. A second set shall be kept in another secure location. Instructions shall contain:

9.2.1 A detailed description of the operation of the system.

9.2.2 An electrical one-line diagram of the electric system showing UPS power source and loads.

9.2.3 A schematic wiring diagram of the UPS.

9.2.4 A function block diagram of the UPS.

9.2.5 Battery specification, installation, maintenance, and wiring diagram.

9.2.6 Instructions for routine maintenance.

9.2.7 Suggested spare parts list with part numbers and parts sources.

9.2.8 Routine troubleshooting procedures.

Basis: *NFPA* 111 (Ref. 10.14), Section 6.2. Compliance with this NFPA code is required per Appendix G of the UC contract.

10.0 REFERENCES

The following references, and associated revisions, were used in the development of this document.

10.1 LIR 230-05-01.0, Operation and Maintenance Manual.

10.2 DOE O 430.1A, Attachment 2 "Contractor Requirements Document" (Paragraph 2, Sections A through C), a requirement of Appendix G of the UC Contract.

10.3 DOE Order 4330.4B, Maintenance Management Program, Section 3.4.9.

10.4 LIR 301-00-02.0, Variances and Exceptions to Laboratory Operation Requirements.

10.5 LPR 230-07-00, Maintenance History, Performance Criteria [2].

10.6 ANSI/IEEE 944, Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations.

10.7 DOE-STD-3003, Backup Power Sources for DOE Facilities.

10.8 LANL LIR 230-01-02, Graded Approach for Facility Work.

10.9 LANL LIR 230-04-01, Laboratory Maintenance Management Program.

10.10 NETA MTS, Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems, InterNational Electrical Testing Association.

10.11 NFPA 70, National Electrical Code.

10.12 NFPA 70B, Recommended Practice for Electrical Equipment Maintenance.

10.13 NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces.

10.14 NFPA 111, Standard on Stored Electrical Energy Emergency and Standby Power Systems.

10.15 DOE-STD-3009, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports

10.16 LANL LIR 402-600-01, Electrical Safety

10.17 LANL LIR 402-860-01, Lockout/Tagout for Personal Safety

10.18 IEEE Std. 446-1995, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

11.0 APPENDICES

Appendix A: UPS Operations Intervals Appendix B - UPS Maintenance Intervals

Appendix C: Expected Life of Components of UPS Systems

Appendix D: Typical Static UPS

Appendix E: Typical Rotary UPS

Appendix F: Typical Redundant Static UPS

Appendix A

UPS Operations Intervals

UPS Operations Intervals Perform operations more frequently if recommended by the UPS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.	**Static UPS**	**Rotary UPS**	**ML2** (NFPA 111 Level 1)	**ML1** (NFPA 111 Level 1)	**ML3 Life Safety System** (NFPA 111 Level 1)	**ML3 Non-Life Safety System** (NFPA 111 Level 2	**Acceptance Criteria**
Perform post repair testing after any UPS system repair or battery replacement. Perform all inspections specified under 6.2.3.1 then test the UPS under connected load for a minimum of 5 minutes or as specified for the UPS class, whichever is less.	**X**	**X**	**After any repair (Required)**	**After any repair (Required)**	**After any repair (Required)**	**After any repair (Required)**	No evidence of problems; meter readings within normal ranges. Supports load and voltages remain within manufacturer's specified range.
Check UPS externally. Check for evidence of problems by evaluating meter readings, sounds, smells, and detrimental environmental problems (heat, moisture, and chemicals).	**X**	**X**	Daily	Daily	Daily	Daily	No evidence of problems; meter readings within normal ranges.
Check all lamps using the "lamp test" feature.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	All lamps operate properly.
Check all meters to ensure they are operating.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	All meters operate properly.
Record UPS meter readings: voltmeter, ammeter, and frequency meter at input and output.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	Meter readings within normal ranges.
Verify that the disturbance monitor is operable, if the UPS system is so equipped.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	Disturbance monitor is operational.
Check the appearance and cleanliness of all equipment, the room/area.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	UPS equipment is clean. UPS room/area is clean and not used for storage.
Inspect the HVAC equipment and measure the room/area temperature and humidity.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	HVAC equipment operating. Temperature and humidity within limits specified by the UPS manufacturer.
Check all UPS equipment air intakes and exhausts, including filters.	**X**	**X**	Weekly	Weekly	Weekly	Weekly	Filters not clogged. Fans operational.
Contact UPS manufacturer for information on equipment upgrades and recommended revisions.	**X**	**X**	Bi-Annually	Bi-Annually	Bi-Annually	Bi-Annually	Action completed.

Appendix B

UPS Maintenance Intervals

UPS Maintenance Intervals Perform maintenance more frequently if recommended by the UPS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.	**Static UPS**	**Rotary UPS**	**ML1** (NFPA 111 Level 1)	**ML2** (NFPA 111 Level 1)	**ML3 Life Safety System** (NFPA 111 Level 1)	**ML3 Non-Life Safety System** (NFPA 111 Level 2	**Acceptance Criteria**
Check the UPS battery and associated charger/control equipment. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Verify that they are in a clean and satisfactory condition and no exceptional environmental or other conditions exist that could damage or affect performance.
When applicable, check the UPS battery electrolyte levels and refill as necessary. Clean and regrease battery terminals and intercell connectors as necessary. Clean cell tops. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Electrolyte levels to battery manufacturer's specifications. No corrosion evident on battery terminals or intercell connections.
Check and record individual cell voltages where practical. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Cell voltages within manufacturer's specified range.
Check and record the specific gravity of pilot cells where applicable. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Specific gravity within manufacturer's specified range.
Note the condition of the plates and sediment of free-electrolyte, lead-acid batteries in transparent containers. (Refer to Criterion 511 "Stationary System Batteries" for additional requirements and recommendations.)	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Condition within manufacturer's specified range.
Perform a load test. Record the UPS output voltage, the battery voltage, and the duration of the test at the beginning and end of the test.	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	UPS supports the load and voltages remain within manufacturer's specified range.
Check that all UPS indicator lamps, meters, and controls are operating correctly.	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	All operating properly.
Check the UPS load value to ensure that it is within the UPS rating.	**X**	**X**	**Monthly (Required)**	**Monthly (Required)**	**Monthly (Required)**	Quarterly	Within manufacturer's specified range.

UPS Maintenance Intervals (cont.) Perform maintenance more frequently if recommended by the UPS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.	**Static UPS**	**Rotary UPS**	**ML1** (NFPA 111 Level 1)	**ML2** (NFPA 111 Level 1)	**ML3 Life Safety System** (NFPA 111 Level 1)	**ML3 Non-Life Safety System** (NFPA 111 Level 2	**Acceptance Criteria**
Measure UPS phase and neutral output currents during peak loading. Measurement should be made using a true RMS type ammeter.	**X**		Monthly	Monthly	Monthly	Quarterly	Verify that the neutral conductor ampacity is not exceeded
Inspect all parts for evidence of overheating.	**X**		Monthly	Monthly	Monthly	Quarterly	No evidence of overheating.
Inspect terminals for loose or broken connections, burned insulation, etc.	**X**		Monthly	Monthly	Monthly	Quarterly	No loose or broken connections.
Check for liquid contamination (battery electrolyte, oil from capacitors, etc.) Inspect inverter for signs of leaking fluid from the wave-forming capacitors; check capacitors for swelling or discoloration.	**X**		Monthly	Monthly	Monthly	Quarterly	No liquid contamination.
Clean the inside of all equipment enclosures and clean the components within.	**X**		Monthly	Monthly	Monthly	Quarterly	Enclosure and components are clean.
Exercise each Level 1 UPS system under connected load for a minimum of 5 minutes or as specified for the UPS class, whichever is less.	**X**	**X**	**Quarterly (Required)**	**Quarterly (Required)**	**Quarterly (Required)**	Semi-Annually	UPS supports load and output voltage and frequency remain within manufacturer's specified range.
Inspect all parts for evidence of overheating.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	No evidence of overheating.
Inspect all parts for evidence of physical damage, including worn insulation and corrosion.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	No physical damage, worn insulation or corrosion.
Inspect terminals for loose or broken connections, burned insulation, etc.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	No loose or broken connections.
Check connections for tightness.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	Connections have proper torque.
Clean the inside of all equipment enclosures and clean the components within.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	Enclosure and components are clean.
Check all bearings and their lubrication. (IEEE 446) Refer to Criterion 510, AC Motors, for additional guidance on maintenance of rotating equipment.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	Bearings are not overheating or noisy and are properly lubricated.
Test alarm shutdown functions.		**X**	Quarterly	Quarterly	Quarterly	Semi-Annually	Alarm shutdown functions performed as specified by the manufacturer.

UPS Maintenance Intervals (cont.) Perform maintenance more frequently if recommended by the UPS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.	**Static UPS**	**Rotary UPS**	**ML1** (NFPA 111 Level 1)	**ML2** (NFPA 111 Level 1)	**ML3 Life Safety System** (NFPA 111 Level 1)	**ML3 Non-Life Safety System** (NFPA 111 Level 2	**Acceptance Criteria**
Check tightness of electrical connections and utilize infrared scanning under load or testing with a digital low-resistance ohmmeter. Clean and re-tighten as necessary.	**X**	**X**	Semi-Annually	Semi-Annually	Semi-Annually	Annually	No loose or corroded connections.
Check and adjust voltage output and frequency according to manufacturer's specifications.	**X**		Semi-Annually	Semi-Annually	Semi-Annually	Annually	Output voltage as specified by the manufacturer.
Test alarm shutdown functions.	**X**		Semi-Annually	Semi-Annually	Semi-Annually	Annually	Alarm shutdown functions performed as specified by the manufacturer.
Perform light-load test.	**X**	**X**	Annually	Annually	Annually	18 Months	UPS output voltage and frequency remains within manufacturer's specified limits. Control switches and meters operate properly.
Perform synchronization test.	**X**	**X**	Annually	Annually	Annually	18 Months	The rate of change of output frequency and the output voltage remain within manufacturer's specifications.
Perform AC input failure test	**X**	**X**	Annually	Annually	Annually	18 Months	The DC source instantly sustains the critical loads. UPS output voltage and frequency remain within limits manufacturer has specified.
Perform AC input return test.	**X**	**X**	Annually	Annually	Annually	18 Months	The rectifier instantly sustains the critical loads and recharges batteries (if used). UPS output voltage and frequency remain within limits manufacturer has specified.
Perform transfer test – (For UPS systems that use a Static Bypass Switch.)	**X**	**X**	Annually	Annually	Annually	18 Months	Transients and transfer times remain within manufacturer's specified limits.
Perform rated full-load test.	**X**	**X**	**Annually (Required)**	**Annually (Required)**	**Annually (Required)**	18 Months	UPS supports rated load for the full duration of its class.
Perform output-voltage balance test.	**X**		Annually	Annually	Annually	18 Months	The output phase-to-phase and phase-to-neutral voltages and angles remain within manufacturer's specified limits for full rated balanced and unbalanced loads.

UPS Maintenance Intervals (cont.) Perform maintenance more frequently if recommended by the UPS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.	**Static UPS**	**Rotary UPS**	**ML1** (NFPA 111 Level 1)	**ML2** (NFPA 111 Level 1)	**ML3 Life Safety System** (NFPA 111 Level 1)	**ML3 Non-Life Safety System** (NFPA 111 Level 2	**Acceptance Criteria**
Perform harmonics-Components test.	**X**		Annually	Annually	Annually	18 Months	Harmonic content in the output voltage for rated linear and non-linear load conditions remain within manufacturer's specified limits for full rated balanced and unbalanced loads.
Check and test all circuit breakers. Refer to Criterion 504, Low Voltage Electrical Equipment, for additional guidance on maintenance of circuit breakers.	**X**	**X**	18 Months	18 Months	18 Months	Bi-annually	All circuit breakers function within limits set by the manufacturer.

Appendix C

Expected Life of Components of UPS Systems

Transformers, Inductors, DC Chokes
The design life of most magnetic components is 20 years of operation. Key factors are the temperature rating of the insulation used in the winding process and the temperature rise while in service. Some commutation inductors have exhibited deterioration after ten to fifteen years of service due to load variations and the constant cycling of the current through the inductor. Before failure, such inductors will start to vibrate and become very noisy. This condition will be obvious during preventive maintenance, and replacement can be scheduled. UPS manufacturers' experience indicates that with proper preventive maintenance, no definitive replacement interval of magnetic components is needed to preclude inadvertent UPS shutdown.

Power Semiconductors
The power semiconductors used in typical UPS systems do not have a rated end of life in the normal mode of operation of the UPS. The only way to tell if a power semiconductor is about to fail is to test leakage current. If it is above the maximum rated value for the device being tested, then the device should be changed.
During the annual maintenance, power semiconductors should also be inspected for corrosion and for damage to the hermetic seal. If corrosion or seal damage is found, the device should be replaced. Otherwise, changing the power semiconductors in large UPS systems is not generally recommended.

Electrolytic DC Capacitors
The expected life of electrolytic capacitors can be calculated as a function of manufacturer's rating and the expected operating temperature of the device. Based on such calculations, the expected average service life is 8 years for capacitors manufactured and purchased before 1988. Due to improvements in the capacitors manufactured and purchased after 1988, the rated service life was extended to 15 years. These service life ratings assume an average room ambient temperature of 30°C (86°F). At a 35°C ambient temperature the average rated service life for electrolytic capacitors is reduced to 11 years; at a 40°C ambient temperature the average rated service life is reduced to only 8 years.

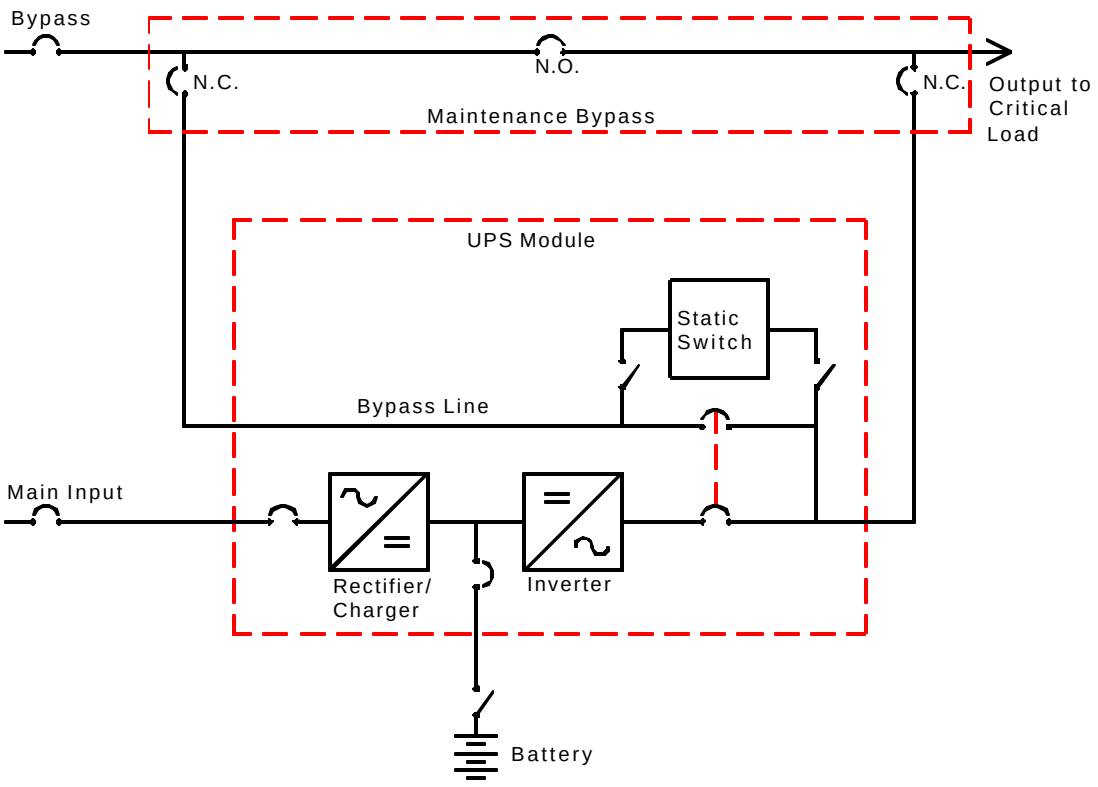
Oil-Filled AC Capacitors
Oil-filled capacitors have an operating life of 10 years. They should be changed at that time due to the internal breakdown of the soggy foils and possible loss of capacitance. All oil-filled capacitors should be inspected and those within 6 months of their service life should be changed out during the annual maintenance. Each oil-filled capacitor should be inspected during annual maintenance for deformation, which indicates that the capacitor needs replacing. Changing AC oil-filled capacitors based on service life is generally not part of most maintenance contracts, but can be included.

Circuit Boards
There is no rated service life for the electronic components used on circuit boards. Circuit boards with problems should be removed and returned to the manufacturer for repair and test. Before they are returned, they should have all outstanding revisions incorporated, and then should be system tested by the manufacturer. If a circuit board fails a second time for the same problem, it should be scrapped. All calibrations should be verified during annual maintenance to ensure that the circuit boards don't exhibit any signs of failure. If any weakness is seen, the circuit board should be replaced.
The most serious limitation to circuit board longevity is availability of replacement components for some boards. Certain parts are no longer available from their manufacturers. Most UPS manufacturers attempt to maintain stock on key components, but it's difficult to foresee all contingencies. This parts-availability issue affects all vendors of both static and rotary UPS products.

The information in this Appendix is based on a White Paper by Liebert titled "Longevity of Key Components in Uninterruptible Power Systems".

Appendix D

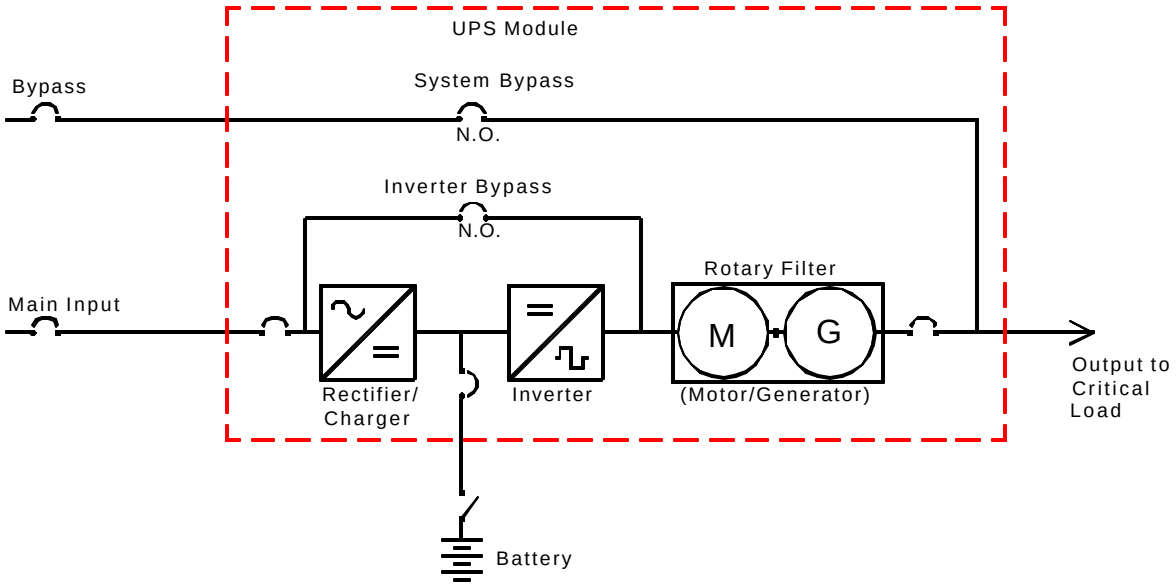
Typical Static UPS



TYPICAL STATIC UPS

Appendix E

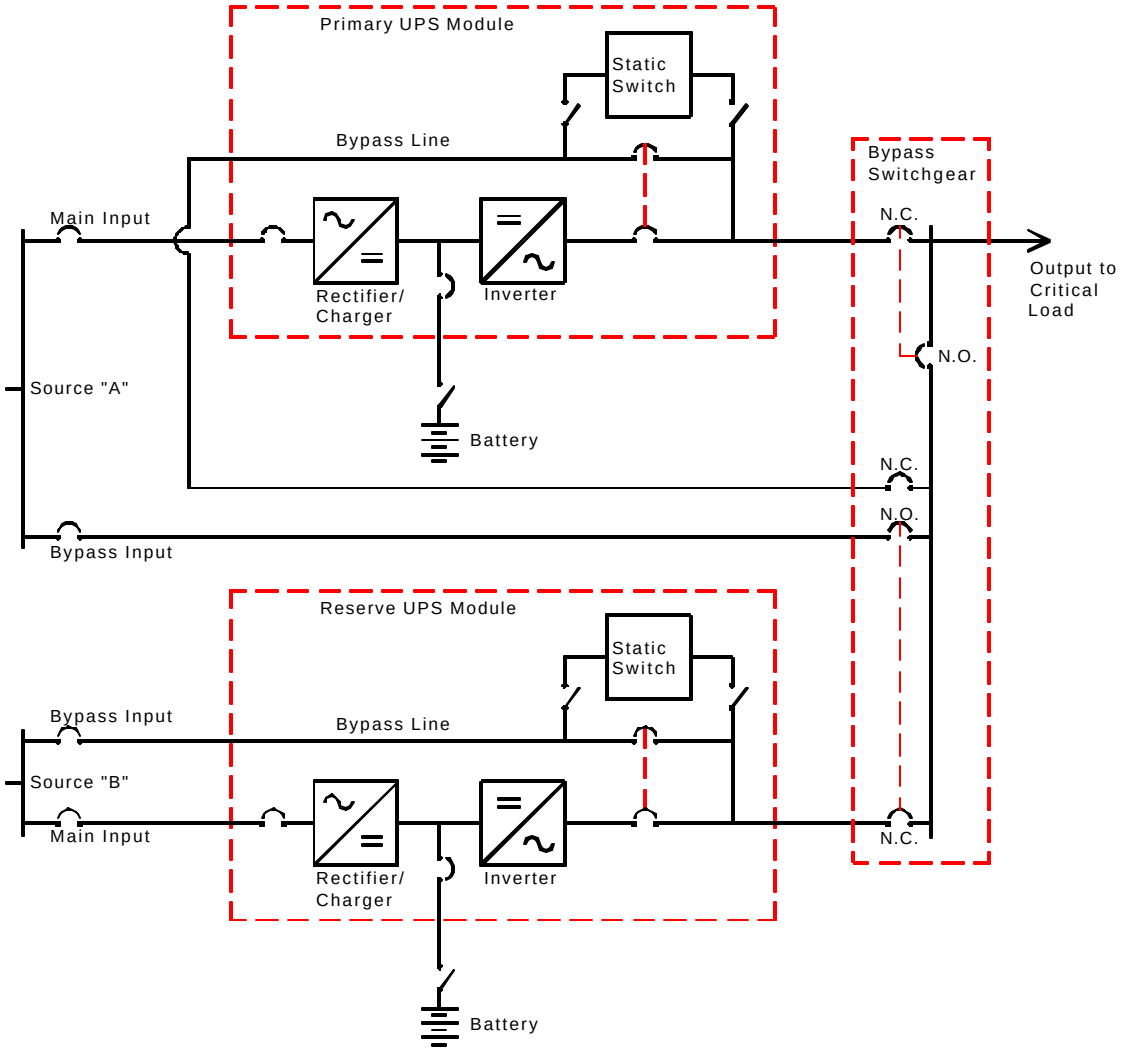
Typical Rotary UPS



TYPICAL ROTARY UPS

Appendix F

Typical Redundant UPS



TYPICAL REDUNDANT UPS